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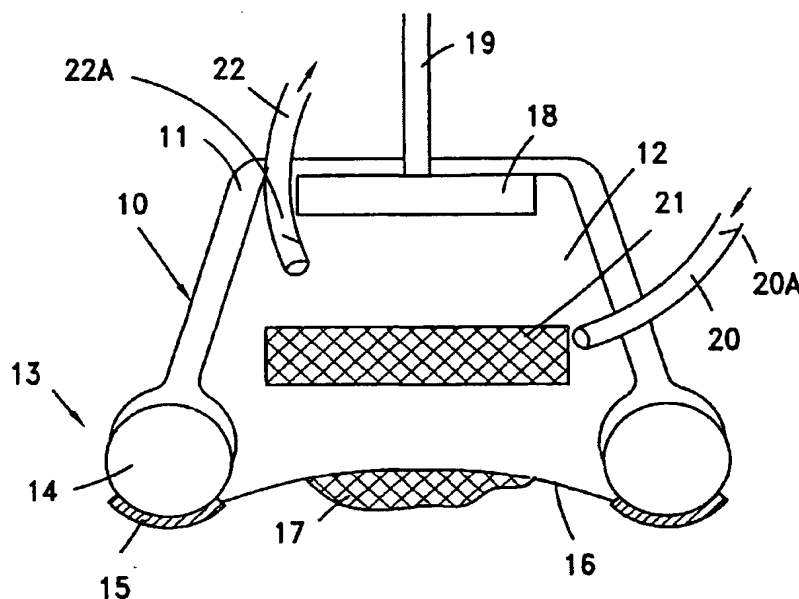
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- (54) Title: SYSTEM FOR ENHANCED CHEMICAL DEBRIDEMENT**



**(57) Abstract:** The present invention relates to a device for the removal of dead tissue from the skin, comprising a chemical or enzymatic debriding agent and an ultrasound probe coupled to means for retaining a debriding liquid agent. The invention further relates to a method for removal of dead tissue from the human skin, comprising contacting said tissue with a debriding agent and concurrently applying to said tissue ultrasonic radiation.

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## **SYSTEM FOR ENHANCED CHEMICAL DEBRIDEMENT**

### **Field of the Invention**

This invention relates to means for the removal of dead tissue, such as eschar and or necrotic tissue. More specifically, it relates to a device for the removal of such tissue, and the preparation of said device and its use for such purpose.

### **Background of the Invention**

Various methods, features and compositions for the treatment of affected skin, particularly of diseased skin areas and burns, are known in the art.

USP 4,372,296 claims a method of treating acne by topically administering ultrasonic vibrations to the acne-affected skin, together with the application of a composition of zinc sulfate and ascorbic acid and a pharmaceutical carrier which is an effective coupling agent for ultrasonic vibrations. This treatment may stimulate the production of collagen in the healing the scars.

USP 5,656,015 describes an ultrasonic therapeutic system which comprises providing a plurality of spaced ultrasonic piezo-electric transducers, which may be so fixed to and around an afflicted area of a patient as to enable the sequential or interlaced excitation, whereby the affected area of the patient can be excited from different aspects. Each transducer delivers its ultrasonic energy via a body of material having a wave impedance that matches that of soft human tissue.

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French Patent Application 2 762 791 discloses a probe which permits the simultaneous application of ultrasound and electrical stimulations, for purposes of medical, paramedical or esthetic treatment.

S.F. Schoenbach et al., in an article in Plastic and Reconstructive Surgery, July 1980, 66(1), 34-37, describe tests carried out on rats for reducing the bacterial count of infected full-thickness burn wounds by ultrasonic treatment.

H.J. Klasen in "A review on the nonoperative removal of necrotic tissue from burn wounds", Burns 26 (2000), 207-222, offers a view of all non-surgical treatment of burns and concludes that enzymatic debridement would seem at first sight an attractive form of treatment, but unfortunately the results are highly variable. In particular, he describes developments regarding proteolytic enzymes including sutilains, collagenase, enzymes of plant origin and other agents.

The diseased or necrotic tissue or eschar, which has formed on the skin of a person for any reason, will be briefly designated hereafter as "dead tissue", and all such kinds of tissue should be understood as being comprised in said designation. Its removal is carried out, in the present state of the art, by mechanical means in an operation called debridement, which may be aided by the use of debriding agents. However, the art has not disclosed any apparatus or means that are effective for the removal of dead tissue and that do not require some degree of surgical debridement.

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Accordingly, it is a purpose of this invention to provide a device that is effective in removing dead tissue, particularly necrotic and/or eschar tissue, that has formed on/in the tissue of a person, without surgical debridement.

Another aspect of the invention concerns the use of a novel device for the removal of dead tissue, particularly eschar tissue.

Other purposes and advantages of the invention will appear as the description proceeds.

#### **Summary of the Invention**

The invention provides a device for the removal of dead tissue from a person, which comprises liquid-retaining means, a liquid debriding agent retained by said retaining means, and an ultrasound probe coupled to said retaining means. Said device generates a novel combination of ultrasonic waves and chemical debriding agents.

The retaining means can be an acoustic chamber or a gel block or any other structural means, that is adapted to retain the liquid debriding agent peripherally, at least after it has been applied to the area that needs debridement. The retaining means must allow the debriding agent freely to contact the dead tissue, and therefore is open at the bottom, and may, in some embodiments, be open at the top. By "bottom" of the device is meant the part that contacts the dead tissue when the device is used, viz.

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the device will be described as if the treated portion of the patient tissue were substantially or approximately horizontal.

The liquid debriding agent may be chosen from efficacious debriding agents. Examples of such agents presently known to the medical art will be listed hereinafter.

Bromelain derivatives (i.e. Debridase, Ananaim, Comosain), Papain derivatives, bacterial derivative enzymes such as streptokinase (Varidase®), Sutilains (Travase®), Collagenase, Trypsin, Fibrolysin-desoxyribonuclease or chemical combinations such as "Aserbin cream®", acids such as Piruric or phosphoric acids.

More particularly, the device of the invention has the following components:

- a) a piezo-electric/ultrasound source unit (hereinafter, briefly, USS) connected to a power source;
- b) spacing means for keeping the USS at the right distance from the tissue to be treated;
- c) an acoustic chamber containing the debriding agent and an acoustic medium;
- d) sealing means between the lower edges of the acoustic chamber and the patient's tissues ("adhesive barrier");
- e) positioning means for holding the device over the dead tissue and preventing its undesirable displacement;

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- f) a chemical or enzymatic debriding agent retained in the acoustic chamber; and
- g) a solvent for the debriding agent, acting as an acoustic medium to promote the propagation of the ultrasound waves, in the form of fluid or gel also retained in the acoustic chamber.

The spacing means may consist in external support for the USS to keep it at the right distance from the tissue or may be constituted by the acoustic chamber itself.

The acoustic chamber may be rigid or soft, e.g., in the form of a flexible plastic body. It may have an inlet port for the debriding agent and/or the solvent and/or an outlet port to produce vacuum to secure the acoustic chamber to the tissue, when so desired, and/or to remove fluids from the chamber. Since the solvent also acts as an acoustic medium, hereinafter it will be called solvent-acoustic medium, or, briefly, solvent-medium.

The sealing means must have sufficient adhesion to prevent undesired displacement of the acoustic chamber during the treatment. In an embodiment of the invention they may be constituted by a seal body, such as a polyurethane foam element or an inflatable cushion or the like, which may be provided with a biocompatible adhesive such as an acrylic glue or a thick gel-like substance, to increase the adherence of the seal body to the skin and seal the acoustic chamber.

The positioning means may be the same as the sealing means or may be different. In an embodiment of the invention, they are constituted by several suction ventoses positioned around the acoustic chamber or a single large ventose that covers entirely the acoustic chamber or constituting a round elastic funnel around the chamber edges. Alternatively, the entire acoustic chamber may constitute a suction cup. As a further alternative, mechanical means such as elastic bandages, straps or adhesive tapes or the like can be used to position the acoustic chamber. When the positioning means are the same as the sealing means, an adhesive layer under the sealing means may hold the acoustic chamber into place.

The solvent-medium may be provided as part of the device before this latter is used, or may be introduced through an inlet port into the acoustic chamber after this latter is positioned and sealed over to the area to be treated.

The ultrasound probe must deliver ultrasound having a frequency measured in Hz and power measured in  $\text{W}/\text{cm}^2$ , for example 20 kHz, and should deliver the ultrasound with a power, for example 10  $\text{W}/\text{cm}^2$ . Another aspect of the invention is the use of a device comprising a liquid debridging agent retained in retaining means and an ultrasound probe connected to a power source, for the removal of dead tissue from a patient's body. The retaining means, as has been said, retain the liquid at the periphery, being open at the bottom and possibly at the top as well.

It should also be clear that the device of the invention can be used for purposes other than the removal of dead tissue.

### **Brief Description of the Drawings**

In the drawings:

Figs. 1 to 4 are schematic vertical cross-sections illustrating various embodiments of the invention, "vertical cross-section" meaning herein a cross-section on a plane which is substantially perpendicular to the surface of the area being treated, and is a symmetry plane of the device.

Figs. 5 to 9 are photographs, illustrating an embodiment of the invention, on which a burn area covered by a dry eschar is shown in various stages of treatment.

### **Detailed Description of Preferred Embodiments**

In Fig. 1, 10 generally indicates a device according to an embodiment of the invention. Since the device is round in shape, all vertical cross-sections are the same and Figs. 1 to 4 represent any such cross-section. The device of Fig. 1 comprises a round cup 11 which is made of any convenient material, e.g., a plastic, which cup defines an acoustic chamber indicated at 12. At the bottom of cup 11 and around its periphery is located a seal generally indicated at 13. This seal comprises a body 14, preferably made of elastic foam, and an adhesive layer 15 which contacts the skin of the patient when the device is in use and retains it in the appropriate position with sufficient adhesive strength. For purposes of illustration, the skin of the patient is schematically indicated at 16 and the dead tissue is schematically indicated at 17. Obviously, the device is so placed as to



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overlay the dead tissue 17. The schematic indication of the skin and dead tissue is not repeated in the following drawings, but should be considered as obviously implicit, in view of the use of the device, which is the same in all illustrated embodiments.

Cup 11 is closed at the top and supports at the top of acoustic chamber 12 portion a USS 18, connected by conductors 19, passing through an opening (sealed if desired) at the top of cup 11, to a power source not shown. In this embodiment an inlet conduit 20 is shown for the introduction of debriding agent and solvent-acoustic medium into the acoustic chamber. The conduit may have a one-way valve 20A. However, the debriding agent can be provided as a unit 21 inserted into the acoustic chamber. 22 is an outlet for creating a vacuum, if desired, in the acoustic chamber to holding against the patient's body and may contain a one-way valve 22A. Since the USS 18 is connected to the inside of the top of container 11, so that its distance from the scar tissue 17 is determined by the height of the acoustic chamber.

Fig. 2 schematically illustrates a device in which a cup 24 that can be made of any flexible film is provided with a peripheral adhesive barrier 23. USS 28 (connected to a power source, not illustrated, by conductors 29) is supported by a spacer 26, illustrated in Fig. 2 as a tripod, but having any other convenient structure. The spacer determines the distance of the USS from the dead tissue to be treated. This embodiment can be held in place by elastic dressing, or tapes applied on top of it (not shown).

Fig. 3 illustrates an embodiment in which a device, generally indicated at 30 and similar in structure to the device 10 of Fig. 1 is held in place by an overlaying element 31, which may be called an anchoring ventose, and which is positioned on the area to be treated by applying a vacuum through an outlet 32. Anchor 31 is preferably provided with sealing means 33, to permit a vacuum being established therein. The device 30 comprises, like the device 10 of Fig. 1, a cup 37, which defines an acoustic chamber 38, supports a USS 34 provided with conductors 35, and is provided with a peripheral seal 36 similar to seal 13 of Fig. 1 which isolates the acoustic chamber 38 from the compartment between overlying element 31 and cup 37, in which a vacuum is created.

Fig. 4 shows an acoustic chamber 40 defined by a cup 41 and retaining a USS 42 with conductors 43. Inlet 44 permits to introduce a debriding agent and the solvent-medium into chamber 40. The sealing and positioning means in this embodiment are provided by annular cavity 46 at the periphery of the bottom of cup 41, in which a vacuum can be created through outlet 47, so that the said annular cavity acts as a ventose to secure the device into place.

The device of the invention may contain, as it is, all its components. The USS may be mounted in it, and the debriding agent and the solvent-acoustic medium be held therein in the form of a consistent component, e.g. retained in a porous or gel-like support. However, it may be generated at the moment of use by conveniently combining its various components. Thus, the USS may be supported by an outside support, that

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is not part of the device, but which permits placing it at the appropriate distance from the dead tissue to be removed; and/or the debriding agent and the solvent-acoustic medium may be introduced into the acoustic chamber through an inlet at the moment of use.

Figs. 5 to 9 present pictures of an "in vivo" animal study illustrating the invention. The model of the experiment was designed to represent a chronic dessicated eschar (a worst case senario for an enzymatic-chemical debridement). The testing animals were young pigs of 20-25 kg of weight. Under general anesthesia and proper monitoring (according to GAP) the bristles along the spine were shaved. The different test areas were marked and photographed. A series of deep contact burns, 2 cm in diameter, were left to desiccate for three days, creating a dry eschar, very similar to a typical old, chronic wound eschar. A circular chamber 3 cm in diameter was glued around each area. The USS circular probe having a diameter of 1.2 cm that covers half of each eschar site was installed with its surface covering the lower part of the eschar at a distance of 3 millimeters. At this stage the chamber was filled with the test material (Debridase and saline) or with the control (saline). A third control site was a similar eschar treated with hydrated Debridase in an occlusive dressing without the use of USS.

Fig 5. represents the burn area inside the chamber with the USS probe in place covering the lower part of the eschar.

Fig 6. represents the burn area inside the chamber with the USS probe in place immersed in the dissolved Debridase after 20 minutes of USS activity (Debridase solution stained with blood).

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Fig 7. represents the burn area after 30 minutes of treatment with Debridase solution and USS. A completely debrided lower area A can be seen under the USS probe, contrasted by the upper pole B, which the probe did not cover and where the eschar remained.

Fig 8. represents the burn area after 60 minutes of treatment with saline and USS. As can be seen, the eschar is completely intact without any signs of debridement.

Fig 9. represents the burn area after 60 minutes of treatment with hydrated Debridase in an occlusive dressing. Some initial debridement can be seen at the edges (marked by arrow C) where the eschar is thinner, but a thick reaming of the eschar remains in the center.

This animal study showed that the use of a debriding agent (represented by Debridase) alone produced a limited debridement as expected for the specific agent. The use of USS without any debriding agent did not have any debriding effect. However, the combination of an enzymatic debriding agent and a locally applied Ultra Sound produced clear and fast results (in a short period of 30 minutes).

While embodiments of the invention have been described by way of illustration, it will be apparent that many modifications, variations and adaptations can be made therein, without departing from the spirit of the invention or exceeding the scope of the claims.

**CLAIMS**

1. Device for the removal of dead tissue from the skin of a person, which comprises liquid-retaining means, a liquid debriding agent retained by said retaining means, and an ultrasound probe coupled to said retaining means.
2. Device according to claim 1, wherein the retaining means is any means adapted to retain the liquid debriding agent at least after it has been applied to the skin.
3. Device according to claim 2, wherein the retaining means is the capable of retaining the liquid debriding agent peripherally.
4. Device according to claim 3, wherein the retaining means is cup-like and open at the bottom.
5. Device according to claim 1, wherein the liquid debriding agent is chosen from the group consisting of chemical or enzymatic agents.
6. Device according to claim 1, which comprises:
  - a) a piezo-electric/ultrasound source unit connected to a power source;
  - b) spacing means for keeping the USS at the right distance from the tissue to be treated;
  - c) an acoustic chamber containing the debriding agent and an acoustic medium;

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- d) sealing means between the lower edges of the acoustic chamber and the patient's tissues;
- e) positioning means for holding the device over the dead tissue and preventing its undesirable displacement;
- f) a chemical or enzymatic debriding agent retained in the acoustic chamber; and
- g) a solvent for the debriding agent, acting as an acoustic medium to promote the propagation of the ultrasound waves.

7. Device according to claim 6, wherein the spacing means is constituted by or is provided within the acoustic chamber.

8. Device according to claim 6, wherein the acoustic chamber is provided with an inlet port from the debriding agent and/or the solvent-medium.

9. Device according to claim 6, wherein the acoustic chamber is provided with an outlet port to produce vacuum to secure the acoustic chamber to the tissue to be treated and/or to remove fluids from the chamber.

10. Process for making a device according to claim 1, which comprises the steps of applying liquid-retaining means, carrying an ultrasound probe and electrical wires for connecting it to a power source, to the spot to be treated, and then pouring liquid debriding agent into it.

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11. Process for making a device according to claim 1, which comprises the steps of providing liquid-retaining means, applying them to the spot to be treated, introducing liquid debriding agent it, and placing an ultrasound probe on top of the liquid debriding agent.

12. Use of a device according to claim 1, for the removal of dead tissue from the skin of a person, substantially as described in the specification

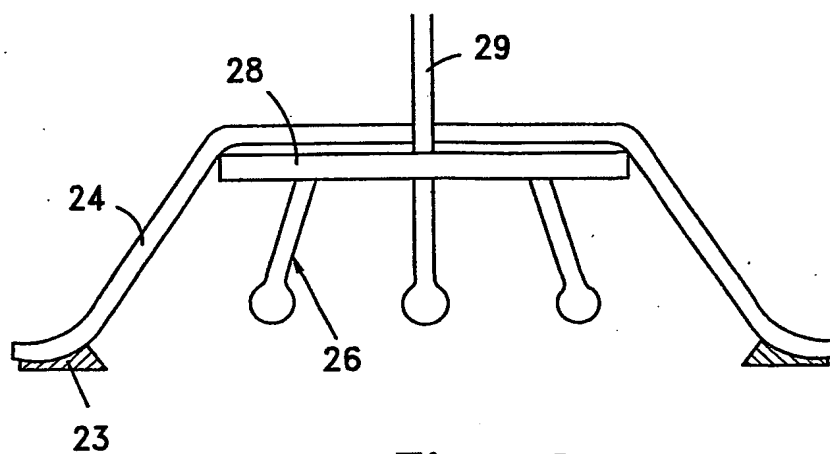
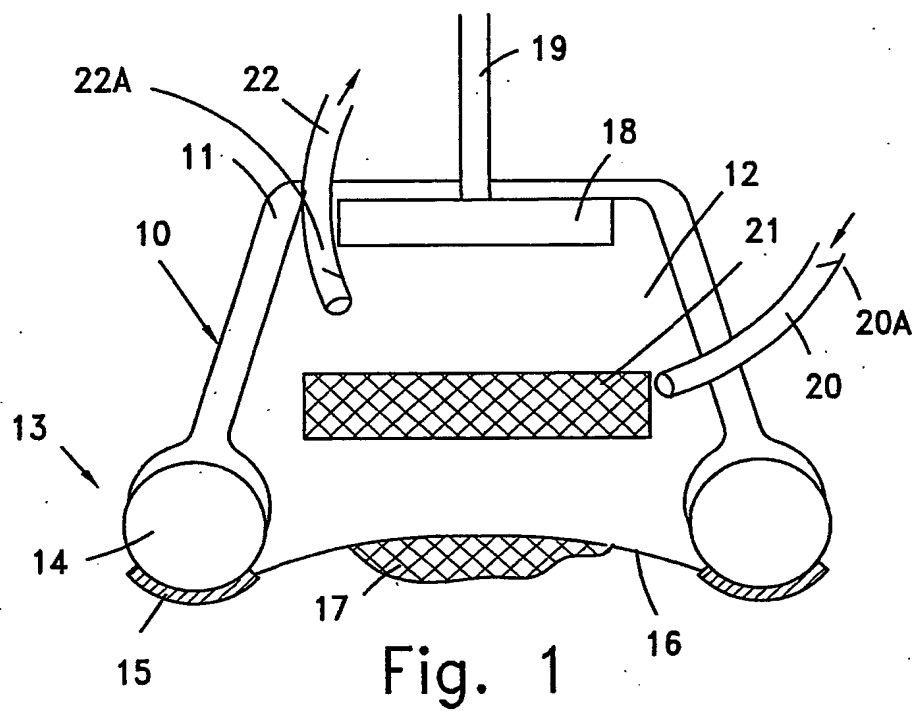
13. Device according to claim 1 for use in the removal of dead tissue from the skin of a person.

14. Method for the removal of dead tissue from the skin of a person, which comprises contacting said tissue with a debriding agent and concurrently applying to said tissue ultrasonic radiation.

15. Device for the removal of dead tissue from the skin of a person, substantially as described and illustrated.

16. Process for making a device for the removal of dead tissue from the skin of a person, substantially as described and illustrated.

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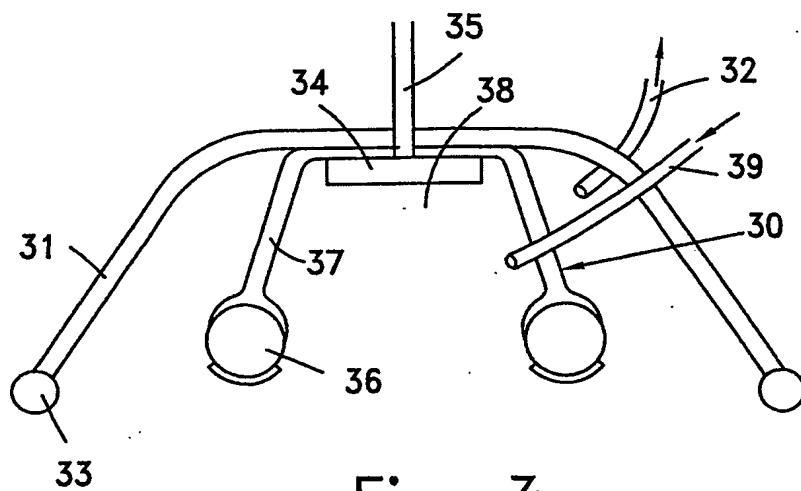


Fig. 3

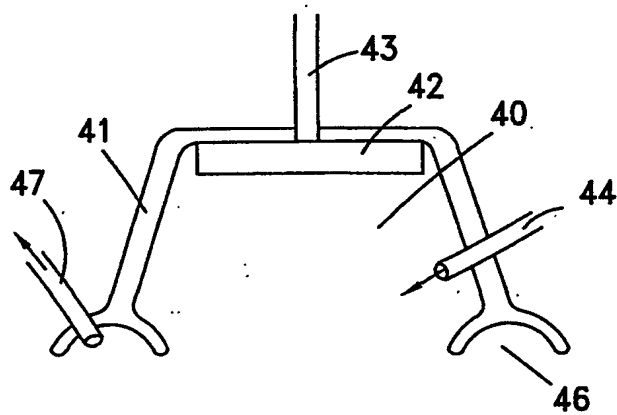
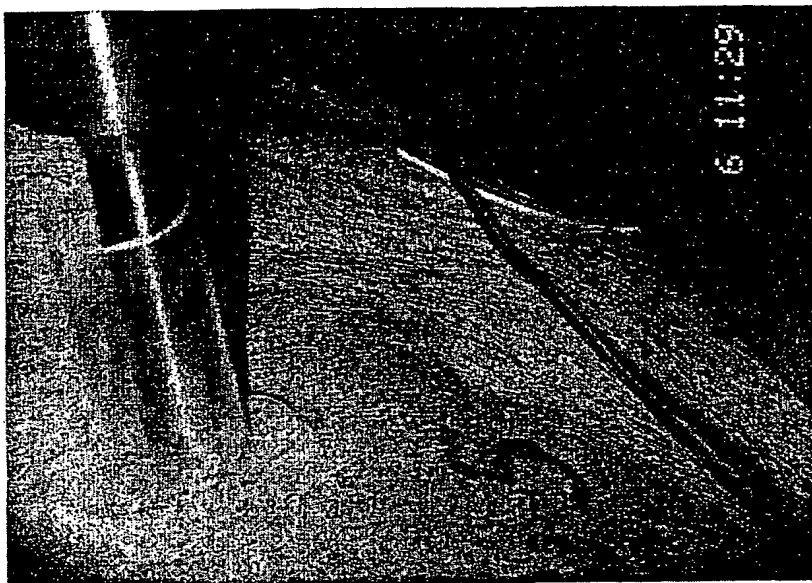
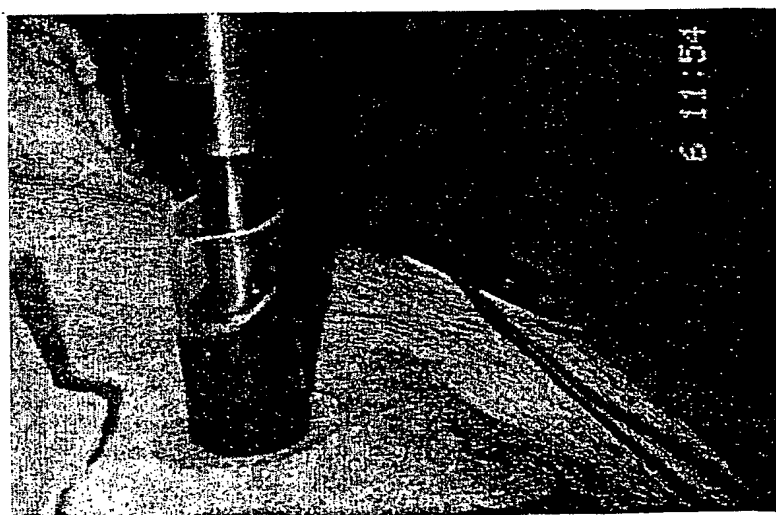


Fig. 4

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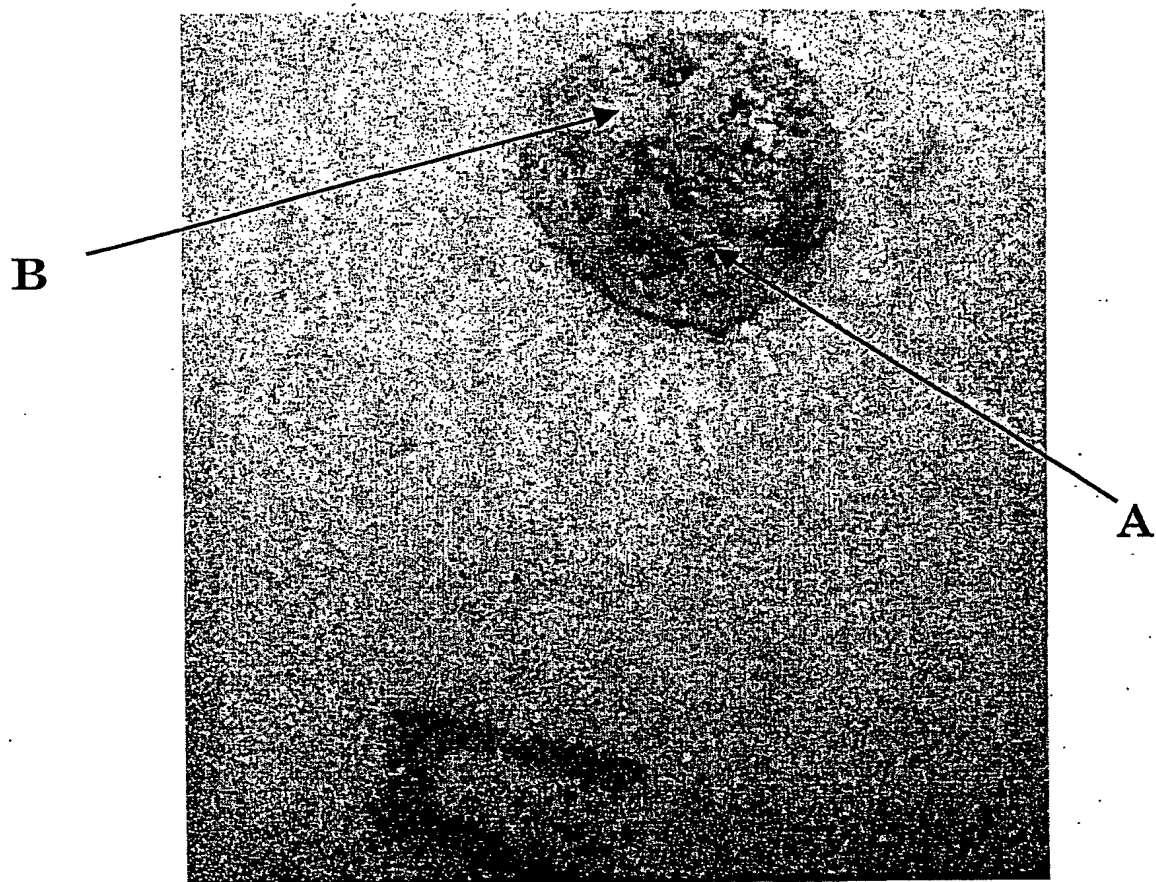


*Fig. 5*



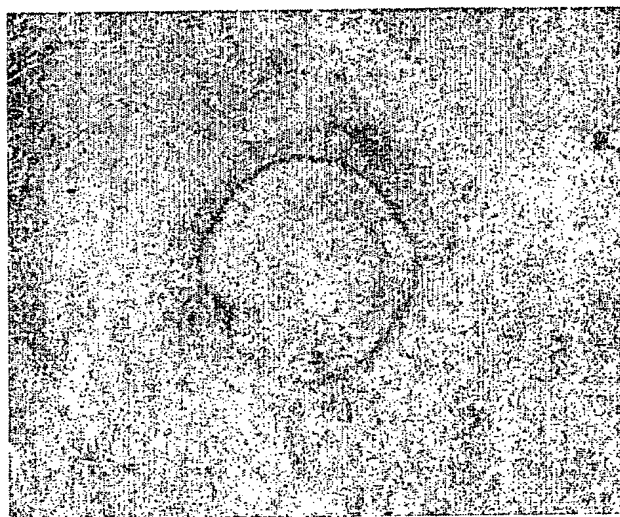
*Fig. 6*

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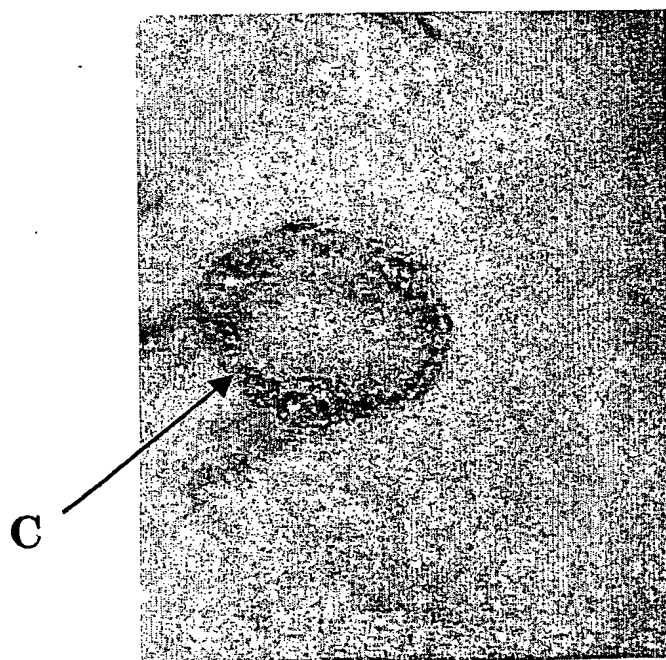


*Fig. 7*

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*Fig. 8*



*Fig. 9*